DRAFT

What Wildland Fire Conditions Minimize Emissions and Hazardous Air Pollutants and Can Land Management Goals Still be Met?

J. Peterson and B. Leenhouts

8/20/97

Introduction

This paper is a discussion of wildland conditions and techniques that minimize pollutant emissions and is intended to provide interested readers with additional information on the subject. This paper was developed by members of an EPA sponsored workgroup in response to specific questions raised about smoke management in the development of a policy recommendation to EPA. In no way should any of the information presented in this paper be construed as an EPA requirement.

Various management techniques can be applied to reduce the emissions produced from wildland burning. Incident emission reductions come almost exclusively from excluding fuels from pyrolytic decomposition by reducing the area burned, fuel loading, or fuel consumption. Cumulative emission reductions may not be realized unless these fuels are either biologically decomposed or permanently removed from the site. The fuels excluded from one incident (prescribed fire) may be consumed by some future incident (wildfire). Emission reduction techniques vary widely in their applicability and effectiveness by vegetation type, burning objective, region of the country, and whether fuels are natural or activity-generated.

Wildfire Emission Reduction

Little thought has been given to reducing emissions from wildfire, but many fire management actions do affect emission production from wildfires because they intentionally reduce wildfire occurrence, extent, or severity. For example, fire prevention efforts, aggressive suppression actions, and fuel treatments (mechanical or prescribed fire) all reduce emissions from wildfires. Although fire suppression often only delays the emissions rather than eliminating them. Allowing fires to burn without suppression early in the fire season to prevent more severe fires in drier periods would reduce fuel consumption and reduce emissions. All fire management plans that allow limited suppression consider air quality impacts from potential wildfires as a decision criteria. So, although we are only discussing emission reduction techniques for prescribed fires in this paper we should remember that there is an inextricable link between fuels management, prescribed fire, wildfire severity, and emission production.

Prescribed Fire Emission Reduction

Emission reduction techniques may reduce emissions from a given prescribed burn area by as much as about 60 percent to as little as virtually zero. Considering all burning nationally, if emission reduction techniques were optimally used, emissions could probably be reduced by approximately 20-25 percent assuming all other factors (vegetation types, acres, etc.) were held constant and land management goals were still met. Individual states or regions may be able to achieve greater emission reductions than this or much less depending on the states or regions biological decomposition capability or ability to utilize available biomass.

Emission reduction techniques (or best available control measures) are not without potential negatives and must be prescribed and used with careful professional judgment and full awareness of possible tradeoffs. Fire behavior is directly related to both fire effects and fire emissions. Emission reduction techniques alter fire behavior and fire effects and can impair or prevent accomplishment of land management objectives. In addition, emission reduction techniques do not necessarily reduce smoke impacts and some may, under certain circumstances, actually increase the likelihood that smoke will impact the public. Emission reduction techniques can cause negative effects on other valuable resources such as soil compaction, loss of nutrients, impaired water quality, and increased tree mortality; or they may be more dangerous or expensive to implement.

Multiple resource values must be weighed along with air quality benefits before emission reduction techniques are prescribed. Flexibility is key to appropriate application of emission reduction techniques and use of particular techniques should be decided on a case by case basis. Emission reduction goals may be targeted but the appropriate mix of emission reduction techniques to achieve those goals will require a careful analysis of the short and long term ecological and social costs and benefits. Air quality managers and land managers should work together to better understand the effectiveness, options, difficulties, applicability, and tradeoffs of emission reduction techniques.

Emissions from wildland fire are complex and contain many pollutants and toxic compounds. Emission factors for over 25 compounds have been identified and described in the literature. A simplifying finding from this work is that all pollutants except NOx are negatively correlated with combustion efficiency, so actions that reduce one pollutant results in the reduction of all (except NOx). NOx and CO2 (not actually considered a pollutant) can increase if the emission reduction technique increases combustion efficiency.

It is generally helpful during discussions of ways to minimize incident emissions from wildland fire to think in terms of the four major factors that influence the amount of emissions produced. These are area burned, fuel loading, fuel consumption, and an emission factor. Examples given in the following discussion are frequently vegetation-, region-, and/or season-specific.

Minimizing Emissions by Reducing the Area Burned

Perhaps the most obvious method to reduce wildland fire emissions is to reduce the area burned. Caution must be applied though and programs to reduce the area burned must not actually result in just a delay in the release of emissions either through prescribed burning at a later date or as the result of a wildfire. Reducing the area burned should only be accomplished by methods that truly result in reduced emissions over time rather than a deferral of emissions to some future date.

Alternatives to fire are least applicable when fire is needed for ecosystem or habitat management, or forest health enhancement. In some areas and some vegetation types when fire is used to eliminate an undesirable species or dispose of biomass waste, alternative methods can be used to accomplish effects similar to what burning would accomplish. Examples of specific techniques include:

- **Mechanical treatments.** This is broad category that can include such diverse techniques as mechanical removal of logging slash from clearcuts, use of animals to graze an area and reduce live vegetation and small twigs, onsite chipping or crushing of woody material and/or brush, and mechanical removal of fuels which may or may not be followed by offsite burning in a more controlled environment. Mechanical treatments may interfere with land management objectives if they cause undue soil disturbance or compaction, stimulate alien plant invasion, impair water quality, or remove material needed for nutrient cycling or small animal habitat. A difficulty with mechanical treatments is that most require good road access which is frequently not available in remote wildlands. Some examples of mechanical treatments include*:*

  1) *Whole tree harvesting and/or yarding of unmerchantable (YUM). Mechanical removal of fuels may result in sufficient treatment so that burning is not needed. This technique is only applicable in activity fuels (debris generated from management activities; especially timber harvest). Since the technique is effective in reducing large woody fuels (those greater than 3 inches in diameter) it is applicable only in forest fuel types (not brush or grass).*
  2) *Firewood sales. Firewood sales may result in sufficient removal of woody debris making burning unnecessary. This technique is particularly effective for piled material where the public has easy access. This technique is only applicable in forest types with large diameter, woody biomass.*
  3) *Other biomass utilization. Woody material can be used for many miscellaneous purposes including pulp for paper, and specialty forest products (wood furniture or art). This category is difficult to define due to the potential diversity of uses. When wood is scarce and pulp prices are high, biomass that previously had no commercial value could suddenly be marketable. Again this is only applicable in forest types that include large diameter woody biomass.*
  4) *Hog fuel for electrical generation. Woody biomass can also be removed and used to provide electricity in regions with cogeneration facilities.*

5) *Ungulates. Grazing and browsing animals (especially sheep, cattle, and goats) can sometimes be used to reduce live grassy or brushy fuels to the degree that burning is no longer required or to reduce fuels prior to burning (increase biological decomposition). Goats will sometimes consume even small, dead woody biomass. However ungulates are selective, favoring some plants over others. The cumulative effect of this selectivity can significantly change plant species composition and long-term ecological processes of an area.*

- **Chemical treatments.** Chemicals may produce effects similar to fire when the objective is to reduce or remove live vegetation and/or species from a site. Certainly chemical treatments can carry their own set of ecological and public relations problems.
- **Concentration burning.** Sometimes, rather than using fire on 100 percent of an area requiring treatment, a subset representing concentrations of fuels can be burned. This can greatly decrease the area burned although the fuel loading of the areas receiving treatment will tend to be high. The total area burned under these circumstances can be very difficult to quantify.

<u>Minimizing Emissions by Reducing Fuel Loading</u>

Techniques that reduce the fuel loading prior to burning result in less fuel available to burn and therefore less emissions. Reducing fuel loading is accomplished by physical removal of fuels prior to burning or scheduling burning before new fuels appear.

- **Mechanical fuel removal.** This category is basically the same as the mechanical treatments category in the previous section except in this case the mechanical treatments are followed by fire. Specific examples of this technique and effects on land management goals are described in the previous section.

- **Burn more frequently.** Frequent, low intensity fires can prevent unwanted vegetation from becoming established on the forest floor. If longer fire rotations are used this vegetation has time to grow resulting in the production of extra biomass and extra fuel loading at the time of burning. This technique generally has positive effects on land management goals since it is likely to result in fire regimes that more closely mimic natural fire frequencies.

- **Schedule burning before new fuels appear.** Burning can sometimes be scheduled for times of the year before new fuels appear. This may interfere with land management goals if burning is forced into seasons and moisture conditions where increased mortality of desirable species can result. Some examples of this technique include:

  1) *Underburn before litter fall. Brushy vegetation drops its leaves in the fall and this litter contributes extra volume to the fuel bed. If burning takes place prior to litter*

fall there is less available fuel and therefore less fuel consumed and fewer emissions.

2) *Burn before green-up. Burning in cover types with brushy and/or herbaceous fuelbed components can produce fewer emissions if burning takes place before these fuels green-up for the year. Less fuel is available therefore fewer emissions are produced.*

Minimizing Emissions by Reducing Fuel Consumption

Meaningful incident emission reduction can be achieved when significant amounts of fuel are at or above the moisture of extinction, and therefore unavailable for combustion. However, burning under moister conditions may leave significant amounts of fuel in the treated area only to be burned in the future. Long-term emission reductions are achieved only if the fuels left behind can be expected to decompose or be otherwise sequestered at the time of subsequent burning. Reducing fuel consumption reduces fireline intensity, crown and foliage scorch, and cambium injury, thus reducing flora and fauna mortality. Spring and elevated fuel moisture burning is frequently used to initiate ecosystem restoration following long-term fire exclusion, recycle nutrients, and "blacken" soils to promote solar soil heating and microorganism growth without significant vegetation mortality.

In the appropriate fuel types, the ability to target and remove only the fuels necessary to meet management objectives is one of the most effective methods of reducing emissions from burning. When the combination of appropriate fuel type and burning conditions can be met, fuel consumption can be greatly reduced. For example, if the objective of burning is to reduce wildfire hazard, removal of fine and intermediate diameter fuels may be sufficient; and the ability to limit large fuel and organic layer consumption will significantly reduce emissions. Examples of this technique follow:

- **High moisture content in non-target fuels.** Burning when internal moisture content of fuels is high, effectively limits their consumption. Intuition might indicate that wet fuels produce *greater* emissions by tending to smolder but in reality, so much less of the wet fuel is consumed that incident emissions are greatly reduced. Here are some examples:

  1). *High, large-diameter fuel moistures. Burning when large-diameter woody fuels (3+ inches in diameter or greater) are wet can result in lower fuel consumption and less smoldering. When large fuels are wet they will not sustain combustion on their own so when the small twigs and branch-wood finish burning, the large logs are extinguished by their own internal moisture. The large logs therefore consume less in total, they do not smolder as much, and they do not cause as much of the organic layer on the forest floor to consume. This can be a very effective technique for reducing total emissions from a prescribed burn area and can have secondary* *benefits by leaving more large-woody debris in place for nutrient cycling. This technique can be effective in natural and activity fuels in forest types.*

2). Moist litter and/or duff. The organic layer that forms from decayed and partially decayed material on the forest floor tends to burn very inefficiently. Consumption of this litter and/or duff layer can be greatly reduced if the material is quite moist. The surface fuels can be burned and the organic layer left virtually intact. The appropriate conditions for utilization of this technique generally occur in the spring (in areas where snow has covered the ground over the winter) or within a few days of a soaking rain. This technique can be very effective at reducing emissions in certain cover types that tend to have deep organic layers. The technique may be more difficult to utilize in cover types where surface roots may be vulnerable to injury from fire under conditions required to make the technique effective or in cover types where removal of the organic layer is desired. Burning litter and/or duff to expose mineral soil is often necessary in fire adapted ecosystems for plant regeneration and biological community integrity. This technique is very effective in most non-fire adapted forest and brush types.

3). *Mass ignition/shortened fire duration. "Mass" ignition can occur through a combination of dry fine-fuels and very rapid ignition which can be achieved through a technique such as a helitorch. Mass ignition can shorten the duration of the smoldering phase of a fire and reduce the total amount of fuel consumed. When properly applied, mass ignition causes rapid consumption of dry, surface fuels and creates a very strong plume or convection column which draws much of the heat away from the fuelbed and prevents drying and preheating of larger, moister fuels. (This strong plume also results in improved smoke dispersal.) The fire dies out shortly after the fine fuels fully consume and there is little smoldering or consumption of the larger fuels and duff. The conditions necessary to create a true mass ignition situation are only possible in open areas with broadcast activity fuels (generally clearcuts).*

4). *Burn before large fuels cure. Living trees contain very high internal fuel moistures which takes a number of months to dry after harvest. If an area can be burned within 3-4 drying months of timber harvest, many of the large fuels will still contain a significant amount of live fuel moisture. This technique is generally restricted to activity-generated fuels in forest-types.*

- **Rapid mop-up**. Rapidly extinguishing a fire can reduce fuel consumption and smoldering emissions somewhat although this technique is not particularly effective and can be very costly. Rapid mop-up primarily effects smoldering consumption of large-woody fuels and duff. Rapid mop-up is more effective as an avoidance technique by reducing residual emissions that tend to get caught in drainage flows and end up in smoke sensitive areas. This technique can be used in forest fuel types.

Minimizing Emissions by Minimizing the Emission Factor

Increasing combustion efficiency, or shifting the majority of consumption away from the smoldering phase and into the more efficient flaming phase, can reduce emissions (except NOx and CO2). The land management consequences of increasing combustion efficiencies are primarily due to increasing fireline intensity (rate of heat release per unit of time per unit length of the fireline). This increases flora and fauna (primarily soil microorganisms) mortality. Keeping other fire regime components constant (burning season, fire rotation interval, etc.), land management goals which require increased fireline intensity (i.e., hardwood shrub control) benefit.

- **Burning fuels in piles or windrows.** Fuels concentrated into piles or windrows generate greater heat and burn more efficiently. A greater amount of the consumption occurs in the flaming phase and the emission factor is lower. This technique is primarily effective in forest fuel types but may have some applicability in brush types also. Concentrating fuels into piles or windrows generally requires the use of heavy equipment which can negatively impact soils and water quality. Piles and windrows also cause temperature extremes in the soils directly underneath and can result in areas of soil sterilization.

- **Backing fires.** Flaming combustion is cleaner than smoldering combustion. A backing fire takes advantage of this relationship by causing more fuel consumption to take place in the flaming phase than would occur if a heading fire were used. In applicable fuel types, the flaming front backs more slowly through the fuelbed and by the time it passes, most available fuel has been consumed so the fire quickly dies out with very little smoldering. In a heading fire, the flaming front passes quickly and the ignited fuels continue to smolder until consumed. This technique is only applicable in natural fuels and in fuel types where the primary ground fuel is grass and/or very fine woody fuels. Without continuous fine fuels (grass, leaves, needles), backing fire spread is impossible. The opportunity to use backing fires is very limited, can increase operational costs substantially, has other environmental consequences, and emission reductions obtained from grass fuels are minor due to the combustion properties of grass.

- **Rapid mop-up.** Rapidly extinguishing a fire results in some minor reductions in smoldering consumption meaning a greater emphasis is placed on flaming combustion and the average emission factor is reduced. For a more detailed description of this technique see the Fuel Consumption section.

- **Mass ignition/shortened fire duration.** This technique, though difficult to apply, can result in a greater amount of the consumption occurring in the flaming phase which reduces the effective emission factor. For a more detailed description see the Fuel Consumption section.